Environmental impact of a new concept of food service: a case study for the re-use of naval shipping containers

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Abstract

This study aims to evaluate the environmental sustainability of a new street food format for food service based on the re-use of naval shipping containers and to compare it with the conventional one (street food truck). The environmental impact analysis was performed using the Life Cycle Assessment methodology. The functional unit (FU) was identified in the food service, including three food preparations: a dish of pasta (100 g), one sandwich (150 g) and one portion of fries (200 g). Following a "from cradle to gate" approach, the factors studied are: (i) the customization of a shipping container in a street food format, (ii) the construction and use of the cooking appliance, (iii) the logistics, (iv) the cooking phase (including final packaging as food cup). The life cycle of ingredients for food preparations has been neglected due to the variability of the products.
The results show that the two higher hotspots are electricity consumed by cooking appliance (35%) and oil used to fry (34%), attributable only to the fries preparation. The third hotspot is imputable to the customized structure, with an average percentage value equal to 15%. Considering the global warming impact category, the customization into a street food format release 1280 kg CO_2eq, while the production of a new container or a new street food truck format implies the emission of 12,800 kg CO_2eq and 20,900 kg CO_2eq respectively. The impact of the customized container (re-used container) weight for 0.04 kg CO_2eq/FU, this value increases 11.6 times for a new container street food format, and 17 times for a new street food truck format.
Overall, quantifying the environmental damage, the results showed how the re-use of a naval shipping container can be a way to reduce the environmental impact of food preparation, avoiding dismissing or building activity of the structure reducing the impact of the structure of about 95% offering a more sustainable street food services.

Keywords: circular economy, street food, collective catering, sustainability, LCA, design

1. Introduction

Since several years, companies and authorities responsible for improving sustainability are showing an increasing interest in the environmental performance of food products (Calderón et al., 2010). Food consumption, which represents a fundamental need for human being, has been identified as one of the most polluting activities in domestic boundaries due to the production and cooking processes (Notarnicola et al, 2017). Indeed, emissions of the major greenhouse gases as CO_2, CH_4, N_2O are closely associated with food preparation steps (Carlsson-Kanyama, 1998). Additional criticisms are noticeable in commercial realities which work with a large number of products and need to produce plenty of foods. In the literature, different studies have been conducted to evaluate the sustainability of food preparation and consumption. Leuenberger et al, (2010) performed a Life Cycle Assessment (LCA) study to evaluate the environmental impact of meals prepared in canteen, comparing vegetarian meal with a meat-based one. Pulkkinen et al., (2016) used LCA approach to evaluate the carbon footprint of raw material production and processing of ingredients for 105 commonly selected lunches, while Casson et al., (2019) compare the environmental impact of the legume-based burger with the traditional meat burger one, considering products and domestic cooking phase. Rivera et al., (2014) have compared the life cycle environmental impacts of a ready and home-made meal consisting of roast chicken meat, vegetables and tomato sauce.

Only few studies consider the service as functional unit, e.g. Baldwin et al., (2011) perform the LCA analysis in restaurants and food services.

Moving to other commercial services which prepare foods for a high number of consumers, the street food reality represents a changing in consumers habits, maintaining the traditionality of a service which has existed since ancient times (Cardoso et al., 2014). The Food and Agriculture Organization (FAO) of the United Nations defined the street foods as "ready-to-eat foods and beverages prepared and/or sold by vendors or hawkers especially in the streets and other similar places" (Choi et al., 2013).

Eating meals outside domestic boundaries becomes a more and more common behaviour, approximatively, 2.5 billion people around the world eat street foods every day (Abrahale et al., 2019). The main advantage of street foods is the ready-to-eat added value of the food, it can be consumed in the same place where is bought or everywhere, without any cooking or preparing phase, offering a good alternative to homemade food (Calloni, 2013). Moreover, from an economical point of view, the street foods are alternative to other realities, having lower costs respect to restaurants, and, some of them allow to have a nutritionally balanced meal outside the home (Privitera and Nesci, 2015).

The street food realities expanded in the market and increased the variety of food offered, giving to the consumers the possibility to join different gastronomic experiences (Anenberg and Kung, 2015; Privitera and Nesci, 2015). The street food realities play a significant role in maintaining country-specific culinary traditions, with growing importance especially for more developed societies, where the interest in gastronomy associated with food tourism is increasing (Abrahale et al, 2019).

The product offered by the different street food formats is not the only aspect that in the last years was influenced. Many of the most recent street food realities take place thanks to the re-use of different structure that after customization can be used as street food formats. Some of these innovative structures can be identified in the empty shipping containers which represent an environmental hazard related to the consumption of raw materials and energy (Obrecht et al., 2017). The repositioning in seaborne shipping networks or repositioning in intermodal transportation networks of the containers can systematically take to manage and relocate empty containers, representing an increase of emissions (Li et al., 2014; Song and Dong, 2012). The re-use of empty or end of life containers can be a way to reduce the overall impact of the supply chain avoiding construction of structures as widely applied in different sectors: housing (e.g. Wenckehof container village in Amsterdam, the Netherlands; Cité A Docks student in Le Havre, France), retail (e.g. a temporary mall in Christchurch, New Zealand) or as temporary hospitals for sanitary crises (Mehnazd, 2019). These can represent a greener option for improving environmental performance besides reducing costs and times.

The circular economy is an economic system designed to be capable of regenerating itself guaranteeing its eco-sustainability. The circular economy has the objective of limiting the input of material and energy, and reusing materials in successive production cycles, minimizing waste. Colley et al., (2020) indicates that processing plants could be exploited circular economy opportunities to improve the environmental impact of the food supply chain.

Nowadays, the re-use of naval shipping containers is consolidated and the importance to apply the circular economy business model in every decision-making step become crucial, necessitating the definition of goals to have a high balance with environmental and social interests (Bortolini et al., 2019; Obrecht et al., 2017). Despite this, scarce information are available concerning the environmental advantages related to the re-use of a naval shipping container in the food sector. Moreover, current literature does not provide analyses related to street food services. Therefore, studies concerning re-use of naval shipping container, street food services, and food preparations are desirable. This study aims to evaluate the environmental sustainability of a food service provided by a re-used shipping container customized into a street food format. The application of the LCA as a decision tool for quantifying the environmental impact of the potential choices at the service design level (Hauschild et al., 2018). The same application can fit perfectly into the circular model of economics, the re-use of a naval shipping container could lead to a reduction of raw materials necessary to build a new street

food format. Furthermore, this solution proposed could be advantageous, reducing the impact of the food service respect to the conventional street food services provided by the market.
The functional unit was identified in the food service, including three food products, a dish of pasta, one sandwich and one fries portion. Following a partial "from cradle to gate" approach, the factor studied consider the customization of a shipping container in a street-food format, the construction and use of appliances, the logistics, and the food preparation. Moreover, through alternative scenario, a more efficient street food service was designed. Finally, comparisons with the conventional street-food format present in the market, i.e. food truck and with a new naval shipping container format were performed.

2. Materials and methods

An environmental analysis of the food service was carried out using the LCA methodology. LCA was applied to the service of the street food format, considering: (i) the extraction of resources, (ii) production of materials incorporated into appliances (iii) use of utilities by appliance to provide food service and (iv) transport to movement the street food container. The cultivation/production phase related to ingredients i.e. pasta, bread, potatoes and relative sausages for pasta and filler for a sandwich, were neglected due to the high variability of products characteristics (e.g. type, quantity and production country of ingredients).

2.1. Goal and scope definition

The goal of this study is to analyse the service offered by the street food format using the LCA method. The aim is to identify the hotspots along the street food preparation service and compare different scenarios proposed by the companies concerned street food format. The study takes in consideration a format obtained transforming a 20-foot naval shipping container (6.054 m length, 2.438 m width, and 2.591 m height) into a street food format which offers three different food preparations. Moreover, it was analysed the service provided by the format during one year in different events in the Lombardia region (Italy).
The functional unit FU, defined as the reference unit of the system analysed (ISO 14040, 2006; ISO 14044, 2006), in this study was identified in the food service to provide three food preparations: a dish of pasta (P) equal to 100 g of served pasta, one 150 g sandwich (S) and one portion of fries (F) corresponding to 200 g.
A partial "cradle to grave" perspective was adopted, neglecting impacts of the food products in the study. As reported in Figure 1 and according to the defined FU, the activities included in the system boundary are: structure customization (re-use of "end-of-life" container), extraction of raw materials (e.g. fossil fuels), tap water withdrawal and cooking input to provide the food service (electricity, oil to fries), use of input for maintenance and final disposal of appliances (e.g. refrigerator, fryer, electric plate for pasta and sandwiches), transport and packaging.

2.2. Life Cycle Inventory

In this section was specified the data regarding the food service provided by the street food format including the appliances and their use based on the number of servings, the events and the trip travelled by container, obtained through direct measurements and interviewing food service operators. To simplify the inventory phase, events and services, transport, appliances and container structure, electricity, water, oil, and packaging were analysed separately.

- *Events and services*

Since street food is ready-to-eat food in a street or other public place, it is necessary to define events to be attended and services to be provided. The analysed street food container was used both in the winter and in the summer season (Table 1). The winter season is characterised by i) one exhibition fair from Wednesday to Sunday; ii) one festival, from Monday to Sunday and iii) two City fairs, three days each (form Friday to Sunday). The summer season is characterized by one Street Food Parade, form Friday to Sunday for 14 weeks.

Direct measurement of the container use during the different events helped to identify two representative days during the week. As reported in Table 1, on Saturday and Sunday, the container reached the highest number of servings, selling an average of 560 portions of pasta, 280 sandwiches and 560 portions of fries every day. However, on Friday the food service recorded decreased to 70 %, while on the rest of the week the values recorded were 50 % respect to Saturday and Sunday.

- *Transport*

As reported in Table 1, the distances travelled by the container depend on the events: i) 110 km for the exhibition fair, ii) 124 km for the festival, iii) 248 km for the two city fairs (124 km each), and iv) 923 km for the street food parade. The distance reported for most of the events represents the distance from the logistic base to the event site, while for the Street food Parade it represents the kilometres performed by the street food service during the entire summer season.

- *Street food appliances and container structure*

The customized structure of the container and the appliances exploited for the FU preparation were identified and reported in Table 2. For each appliance primary data from technical sheets helped to report the weight and the material composition, i.e. steel, electronic parts, glass and cast iron. The material composition was identified and reported in values ranged from 0 to 1. The allocation, reported in the last three columns, represents the percentage of usage of appliances to provide the different food preparations.
The structure of the street food format has been recovered from the end of life of the shipping container life cycle. The customization of a shipping container to food service structure avoids the decommissioning processes for the shipping company and avoid the construction of a new container for the street food company. Considering the avoided construction of the new container, the production of this street food format is directly linked to the processes necessary to modify the recovered container and obtain a street food format (creation of ventilation systems, creation and welding of windows and doors for service, and painting). The material and electricity necessary to transform the container into a street food format were assumed equal to 10% (precautionary assumption) of the energy and material necessary to build a 20’ naval shipping container.
The container structure allocation criteria have been defined following a mass allocation based on usage of the respective appliances as reported in the last three columns of Table 2, 47% of the environmental impact of the container has been allocated to the pasta, 18% to the sandwiches and 35% to the fries. The lifetime of the container was set at 15 years. For appliances characterized by a lifetime shorter than 15 years, multiple appliances were considered to satisfy the time limit.
Moreover, considering that the weight of the container is equal to 2200 kg, and the weight of all the appliances correspond to 851 kg (for a total of 3051 kg), the transport allocation follows the container structure allocation criteria: 47% of the transport impact has been allocated to the pasta, 18% to the sandwiches and 35% to the fries.
The end of life of the structure and the appliances follow different decommissioning flows depending on the type of product analysed. The container is treated following inert material operations (metal scrap) while appliances follow the Waste Electrical and Electronic Equipment waste management system.
Finally, an environmental impact comparison with a conventional truck generally used for the street food services was performed. A generic lorry of the size class 7.5-16 metric tons gross vehicle weight (GVW) was chosen as suitable GVW class for potential lorries used in the street food services, using secondary data. The truck structure for street food formats and for the lorry is the same. No appliances were considered due to the possibility of installing the same appliances in the two systems (alternative trucks vs naval shipping container).

- *Electricity*

For each appliance defined and reported in Table 3, different time of utilization and hence different electricity consumptions were required for the food service. In Table 3 power absorption (kW), the working time (h), electricity consumption (kWh) and electricity allocation (based on the utilization time) per food service were reported. To quantify the electricity consumption of appliances based on real cases analysed, three scenarios, 100%, 70%, and 50% of potential production, were investigated. Direct measurements defined that the street food format analysed was used for 8 hours/day, approximatively from 11:30 am to 03:00 pm for the lunch turn and from 06:30 pm to 11:00 pm for the dinner turn. Despite this, some appliances characteristics were considered working continuously, independently from the production level working turns (i.e. refrigerator freezer to conserve frozen pasta and fries, refrigerated display for the sandwiches and refrigerated table for the sausages).

The concept of the street food format has been envisaged to create a solution for energy-autonomous. The use of photovoltaic system (PV system) for electricity production has rapidly increased in recent years (Gerbinet et al, 2014), and it represents one of the more promising renewable energy technologies which has the potential to contribute significantly to sustainable energy supply and which may help to mitigate greenhouse gas emissions (Sumper et al, 2011). During the design phase of the customized container, feasibility problems have emerged limiting the application of PV system to produce renewable energy to supply the total energy requirement for the food service. The analysed street food format to be accessorized with 12 photovoltaic panels on all the 17.28 m^2 available surface (roof and mobile lateral part of the format), corresponding to a power of 2.16 kW and estimated daily production of 8 kWh to partially supply the energy required.

- *Water and frying oil*

Even if water and oil are not considered as part of ingredients, they were considered as consumable products to obtain the food service.

Water used to cook pasta was quantified to 1.6 dm^3 for a portion of pasta. For one day with the 100% production level, 896 dm^3 of water have been used, 640 dm^3 for the 70 % and 448 dm^3 for the 50% production level day.

Fries preparation implies the use of rape oil. The fryer appliance is equipped with two tanks of an overall capacity of 12 dm^3. For the 100% production level, the frying oil was changed two times and 24 dm^3 of oil were used. For the 70 % production level the oil was changed 1.5 times and 18 dm^3 of oil were used, while for the 50% production level only 12 dm^3 of oil were employed.

Oil at its end of life stage is collected and follow the waste cooking oil chain.

- *Packaging*

Independently from the different packaging geometry, the composition was the same for all the food preparations (95% paperboard and 5% polyethylene). The differences are related to the weight, depending on the food preparation: pasta is served in a 450 ml food-cup (13.5 g), a sandwich is served in a box (13.5 g) and fries are served in a 400 ml packaging bowl (8.7 g). Each of which is served with a napkin per product. Only for pasta was considered also a polypropylene fork (2.5 g).

For packaging and paper used in the street food format was considered European plastic and paper waste management scenario.

- *Alternative scenario*

According to the variability of the events analysed, alternative solutions were evaluated to quantify environmental benefits.

The first scenario foresaw to modify the summer event: street food format positioned in an exhibition park for concerts or festivals instead to preside over the street food parade. Each event lasts 3 days per week (from Friday to Sunday) with the same production levels identified. This scenario covers 12 summer weeks. The truck covers in this case only 88 km.

The second scenario regarded frying oil. In the alternative scenario, the rapeseed oil was replaced with sunflower oil.

The third scenario planned to modify the packaging according to two options: the first option was to replace the paperboard and polypropylene of the packaging with a cellulose pulp, the second one was to replace plastic forks with the polylactic acid ones.

3. Life cycle impact assessment

According to Wolf et al. (2012), ILCD 2011 (International Life Cycle Data System) midpoint method was used. The study was conducted according to the reference standards for LCA ISO 14040-14044:2006 (ISO 14040, 2006; ISO 14044, 2006), using the software of analysis SimaPro (version 9) (PRé Sustainability, Amersfoort, The Netherlands) and basing the study on Ecoinvent 3.5 database (allocation, cut-off by classification).
The impact categories, the relative units, and acronyms were used, as summarized in Table 4.

- *Multivariate analysis*

Finally, due to the presence of several factors (structure, transport, electricity, water, oil, packaging) characterizing the food service, a multivariate approach for a qualitative analysis of the data is needed to identify the main factors which affect these types of street food format. Therefore, the variability of the environmental data was analysed in terms of Principal Components (PCs) using the Principal Components Analysis (PCA). This technique is a well-known unsupervised linear technique for dimensionality reduction. PCA is an explorative analysis which extracts the useful information contained into the data and summarizes it graphically for an easier interpretation (Malegori et al., 2018). PCA is useful to reduce the dimensionality of a data set consisting of a larger number of interrelated variables while retaining as much as possible the variation present in the original data set (Jolliffe, 2003; Wold et al., 1987). This is achieved by transforming to a new set of variables, the principal components (PCs), which are uncorrelated, and ordered so that the first few retain most of the original data variation (Lu et al., 2008). PCA can be done by eigenvalue decomposition or singular value decomposition of a data covariance matrix, usually after standardizing the attribute data. The outputs of a PCA are usually graphically discussed in terms of scores (the behaviour of the objects in the PCs space), loadings (the weight of the standardized original variables) and scores and loadings biplot (behaviour of the objects and weight of the original variables visualized in the standardized space of PCs) (Shaw, 2009; Olawoyin et al., 2014; Giovenzana et al., 2019).

The PCA data processing was carried out on Matlab® environment, version R2017b (The MathWorks, Inc) and using the PLS Toolbox, version 8.7.1 2019 (Eigenvector Research, Inc). The original data set was built using as many objects as many are the combination of impact categories, food preparations provided by the service and events considered. Therefore, for each impact category related to each food preparation (P, S and F) and each event (exhibition fair, festival, city fair and street food parade), the structure, transport, electricity, water, oil, and packaging required (factors used as standardized original variables for PCA) were analysed.

4. Results and discussions

The results of the environmental impact calculation for the food service are reported in Table 5.

The food service took into account servicing based on the events, the related distances travelled by the container for the events, the different food preparations, the factors required in terms of structure, appliances, transport, electricity, fry oil, water and packaging, and the allocation for electricity and appliances. The results reported (table 5) in a disaggregate way (per pasta, sandwiches and fries) helped to summarize the results considering the FU and to describe in detail the different events. To better understand contributions linked to the food service, Figure 2 reported the hotspot values in stacked columns, where the total (cumulative) of stacked columns always equals 100 %. No distinction in term of the event was performed and the result reported explain the percentage values of an average preparation of the three different food preparations in the life cycle of the street food format.

The higher average impact can be attributed to the preparation of the fries, it shows positive percentage values from 35% in Mineral, fossil & ren resource depletion (RRD) to 98% in Land use (LU), with an average value equal to 48%. If for most of the impact categories the positive values of the preparation of the fries mean environmental damage, different behaviour can be identified in the Climate Change (CC) impact category, where it shows -1% value. This negative value is directly linked to the positive effect that the cultivation phase of rape oil has on the environment, reducing the CO_2 emitted in the atmosphere.
The second higher impact derives from the pasta preparation. The quantity of water and especially the electricity consumption rise the impact level of this preparation process. The average percentage value is equal to 25% and the impact category values ranged from 1% in LU to 59% in CC. According to Table 5 and matching the impacts related to pasta preparation to Figure 2, the electricity required from the exhibition fair is completely derived by the country mix, with no contribution of the PV system (the event is located inside pavilions), this increase the level of impact of the pasta preparation in this event respect to the others.

The lower values are attributable to the sandwich preparation (18% average), the lower number of appliances necessary and the lower allocation factor respect to the other preparations placed the sandwich one to percentages ranging from 1% (LU) to 42% (CC).
Figure 3 reported the environmental impact related to the events. The results are reported in two different modes for each impact category: the left columns represent the events considering the FU, otherwise, the right columns report the four events but considering 1 year of activity as the reference unit.

Considering FU column, the exhibition fair, which is the event which provides a reduced number of services and requires 100% of the electricity from the grid (the PV system can't be used in this event), is the event that shows higher impact values (e.g. CC 0.273 kg CO_2 eq). The street food parade, characterized by a higher amount of services provided, is the event presenting the lowest environmental impact values (e.g. CC 0.193 kg CO_2 eq). The results are largely different switching the allocation criteria from the FU to 1-year service. The street food parade which for the FU criteria shows the lower impact, considering the 1-year service, shows the one with the largest impact in every impact category. Obviously, in all the impact categories the higher value related to the 1-year service depends on the summer event. The differences highlighted between the two criteria were imputable to a large number of services provided during street food parade, respect to other events (as reported in Table 1). Considering that over 900 kilometres were travelled for the street food, an alternative scenario, characterized by a shorter distance (90 km), should be an efficient solution to reduce the environmental impact.

Figure 4 reports the environmental impact according to factor necessary to provide FU. For most of the impact categories, the higher values come from electricity with values ranged from 2 % (LU) to 62 % (IRHH) and an average percentage among the categories equal to 35 %. Even if the street food container is equipped with PV system which supplies for only 4% of all the electricity necessary, the electricity required for the FU preparation is the main environment damaging factor for most of the impact categories. The second hotspot is the rape oil used to fry (34% average among impact categories). Even if the rape cultivation implies a positive effect of the environment explained by CC impact category (-25 %, already shown in Figure 2), it highlighted negative effects in the other categories, especially for LU. The third hotspot is the structure, with an average, among impact categories, percentage value equal to 15 %. The structure includes the PV system, the appliances and the structure of the container. Even if the container production counts zero-emission (re-use), the container impact is due to the customization activities to convert the naval shipping container into the street food format. Considering the average percentage values, the packaging and the transport showed 7% and 6% respectively. Finally, analysing the impact of structure and appliances end of life scenario, it has been quantified lower than 1% in every impact category. Therefore, they are not reported as hotspots.

One of the main criticisms of a multi-variable LCA analysis is the limit of the evaluation of the effects of the variables allowing a qualitative assessment among the factors, events and food preparations at the same time. The application of principal component analysis (PCA) allows a better understanding of the underlying information about variable correlation. PCA was performed to evaluate the effects of the variables. To perform the analysis the data were centred (according to the average value of each variable) and scaled (according to unit variance) to give the same starting weight to all variables (Todeschini, 1998). Figure 5 shows the PCA scores plot where the samples were coloured according to the type of event. More than 80% of the total variability was explained using only two variables (PC1 63% and PC2 18%). However, no trends or cluster were highlighted colouring the sample according to the type of event. Therefore, the location has no particular effects from an environmental point of view.

Figure 6 a and b show the PCA biplots built using the same dataset. In figure 6a the samples were coloured according to the impact categories, counting twelves times the same category, due to the complex matrix used as PCA input (impact for P, S and F, and for each event). Figure 6a allowed to figure out the main categories causing environmental impact of food service, i.e. Human toxicity, cancer effects (HT-C) and Human toxicity, Non-cancer effects (HT-NC), categories evaluating human health, and Freshwater ecotoxicity (FECO), the category related to the ecotoxicity. Moreover, Figure 6a highlighted the major impact due to structure, transport and mainly to the use of fry oil (positive value of PC2) and packaging, electricity, and mainly water (negative value of PC2). Since PC1 explains the 62.75 % variability of the data, HT-C shows a higher impact on PC1. Others impact categories, result located at negative values of PC2 based on their low impact respect to categories mentioned before.

Figure 6b shows the samples coloured according to the type of preparations. Three clusters were highlighted from negative to positive values of PC2. Pasta, at a negative value of PC2 and positive value of PC1, as well as fries, at a positive value of PC2 and positive value of PC1, result, among the food preparations, the more impacting due to water and oil use, respectively.

- *Alternative scenarios analysis*

The alternative scenario analysis can help to identify the benefits or the disadvantages, changing different factors in the system analysed. Figure 7 shows variations in the different scenarios, where the negative values represent benefits and the positive values represent disadvantages.

Considering the three factors analysed in the alternative scenarios, the choice to create an alternative summer event, replacing the street food festival with a static one shows convenience in term of environmental impacts, the reduction in CC impact category is equal to 17%. This reduction can be seen also in PM (-13%) and POF (-18%), directly linked to the high reduction of trips the container has not to perform. An overall reduction of -12% can be assumed as the average benefit in changing the summer event. Another positive effect was highlighted by changing the packaging with a bio-based product. The reduction of impact in term of CC recorded a -35%. Despite this significant reduction in CC impact category, the overall average advantage is identified equal to -3%. If changing the packaging could mean a benefit for the environment, on the other hand, it could mean an increase in the costs of the alternative packaging. Finally, the choice to replace the rapeseed oil with the sunflower oil increases the environmental impact of the system. The higher value recorded is visible in Water Resource Depletion (WRD) impact category (+286%) while the higher benefit is recorded in LU impact category (-75%) due to the higher yield respect to the rape one.

The street food format was obtained re-using a naval shipping container. Analysing the environmental cost only from the CC impact category point of view, the environmental cost depends only on the customization of the naval shipping container to obtain the street food format layout identifiable in 1280 kg CO_2 eq. The real benefits of re-using a naval shipping container are the avoided production of a new one (Intermodal shipping container 20 foot, production, Ecoinvent 3.5) which requires 12800 kg CO_2 eq and the avoided production of a new street food truck format assumed similar to lorry of the size class 7.5-16 metric tons gross vehicle weight (GVW) (Ecoinvent 3.5) which requires 20,900 kg CO_2 eq. Considering the option to use a container to create the street food format, it is convenient the re-use of the container due to -12,800 kg CO_2 eq and also it is convenient compared to the construction of the food truck -19,620 kg CO_2 eq. From the initial scenario where the impact of the customization weight for 0.04 kg CO_2 eq per FU, the necessity to build a new naval shipping container street food format let the environmental impact derived from the construction increase of

11.6 times and in the scenario of a new street food truck format, this value increase of 17 times per FU. An increase of 11.6 times means 0.53 kg CO_2 eq more for each FU, while an increase of 17 times, means 0.82 kg CO_2 eq per FU.

This study does not consider the life cycle of the foods served. Foods present in the market are plenty as well as their relative environmental impact, which importance is continuously remarked in the food LCA studies, also considering nutritional aspects. The reduction of the environmental impact also related to the food choice should allow to design a low-emission street food format.

5. Conclusions

Eating meals outside domestic boundaries have become a habit for billions of people worldwide. The differentiation of the product is not the only variability of the street food system, in fact, many of the most recent street food realities, approaching to the concept of more sustainable service, take place thanks to the re-use of different structure that after customization can be used as street food formats. The end-of-life naval shipping containers represent an environmental hazard related to the consumption of raw materials and energy for its dismissing but could become a benefit if re-used for a second life following the circular economy business model.
The LCA study highlighted how the electricity required by appliances and oil used for fried products are the main drivers of the environmental impact in the street food service. Considering the average values among the impact categories, the fries' preparation was identified as the most environmentally damaging (53%), the second was the pasta preparation (27%) and the third was the sandwiches preparation (20%).

Overall, quantifying the environmental damage, the results showed how the re-use of a naval shipping container can be a way to reduce the environmental impact of the whole service, avoiding dismissing or building activity of a new structure, reducing the impact by 95%. Considering that food production has a large impact on environment and street food services are nowadays expanding, the use of the circular economy model as proved in this study can increase the environmental advantages of food processes.

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